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TECHNOLOGICAL ACCELERATOR WITH CLOSED ELECTRON DRIFT FOR SURFACE TREATMENT

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Now the technologies of functional covers deriving on large surfaces intensively are developed. For these purposes the plasma sputtering systems of magnetron, vacuum - arc, electron -beam and other types are effectively used. The quality of cover largely depends on preliminary treatment of a surface - its clearing and activation.

In the paper is shown, that the anode layer thruster (or the anode layer accelerator – ALA) intensively cleans a surface of target body in a narrow pressure range of working gas in a system. On absolute rate of cleaning (~ 1 nm/s) ALA do not concede to a Kaufman sources. The injection of gas in the accelerator through electrodes with success can be replaced by injection immediately in volume. In this case the rates of sputtering increase approximately twice. The optimal pressure for cleaning essentially will increase, that does ALA compatible with a magnetron on pressure of working gases.

INTRODUCTION

The rough growth the state of art a high-tech technology determines a increased interest to plotting new functional covers (including multilayers) with complicated stechiometry both on metals, and on dielectrics. For these purposes the plasma spray systems of magnetron, vacuum - arc, electron-beam types and other are effectively used [1]. The quality of cover largely depends on preliminary preparation of a surface - its clearing and activation. Best if this operation is carried out directly ahead of plotting of a film in a uniform work cycle. In microelectronics this problem is successfully decided by use, generally, of a Kaufman type sources [2].

Alternative in relation to devices with heated cathodes are the stationary plasma accelerators with the closed drift of electrons (for example, anode layer accelerator) and some other systems of ion plasma etching.

Despite of external attractiveness of a system, the accelerators with an anodic layer were used earlier in main as sources of ions and electro-rocket engines. Their capabilities as means of clearing and activation of surfaces are circumscribed and rather incomplete [2,3]. On the other hand, their application in a unified work cycle in a pair with, for example, continuously working magnetron superimposes on ALA a number of supplementary claims.

In the present work is developed and investigated the compact technological thruster with the closed drift of electrons in crossed E and H fields as a means of cleaning and activation of a substrate directly ahead of deposition of functional coatings.

EXPERIMENTAL SETUP

All experiments are carried out on the setup the schematically represented on a fig. 1. The researches were conducted with use ring-type(annular) ALA of a classical configuration. Width of a channel made 1 cm. As the system was designed for the technological purposes, the single-stage version was developed for it of simplification and price reduction at use of permanent magnets. For the same reason forced compensation of a space charge of an ion beam was not applied. The cathode of the accelerator has ground potential, and a constant voltage up to 1500 V was applied to anode. Working gas is argon. In experiments it was possible to inject gas to the chamber as through a source, pursuant to a classic design of the device, and directly in volume. The dielectric target (usually glass) is placed in 7 cm from the accelerator.

The special attention was given to measurement of sputtering rates of surface layers on the target depending on various parameters of system. Measurements of sputtering rate were carried out in a following way. A bright-up lamp is placed near an accelerator channel and a photodiode is placed behind the glass target (see Fig. 1). Regime of their operation was chosen in a way that the discharge glow in accelerator channel practically doesn't affect on photodiode indications. Copper straps are applied on the internal and external cathodes. First, the system is set in a sputtering regime (see below), when copper is deposited on the substrate glass due to the channel straps sputtering. This leads to decrease of photodiode EMF. Then the system is set in an etching

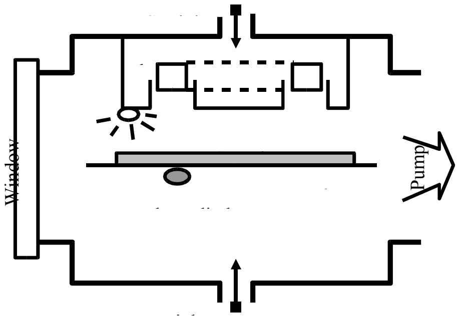


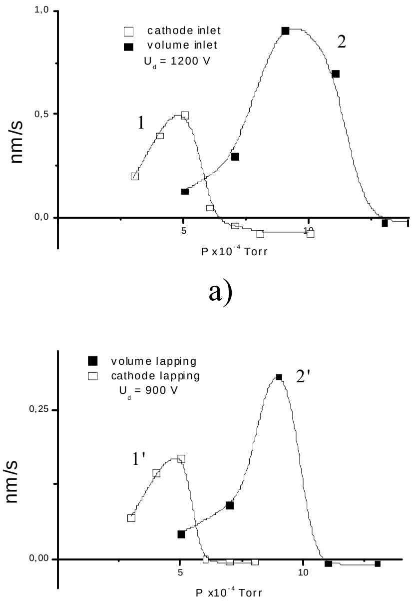
Fig.1. The scheme of the experimental setup. The circle anode –A ; The cathode with the built-in magnetic system – C.

regime and plasma beam clears away the target from the initially deposited copper. It is readily to calculate the rate of substrate cleaning (in relative units) using the recovery time of initial EMF of photodiode. In addition to this we cleaned in the accelerator a few samples of glass, which have a copper coating of known thickness. They are produced by method of thermo-ion deposition. At the same time the state of coating was controlled by photodiode. It makes possible to calibrate a measuring system and find out the absolute values of etching rate.

RESULTS OF MEASUREMENTS

Dependencies of cleaning rate on pressure in a vacuum chamber under constant voltage on an anode are presented in Fig. 2. Curves 1 and 1' correspond to the common gas inlet into the system. It is seen that curves have a bell-like shape and achieve a maximum in a region 4-5.10^{-4} Torr. Decrease of pressure leads into a drop of cleaning rate. Nevertheless, it is positive down to zero. For the pressure above 6.10^{-4} Torr the cleaning regime is substituted by sputtering. Causes of such behavior will be discussed below. In a range of pressures 4-5.10^{-4} Torr the discharge is sustained up to ~350 V when a voltage is decreased. The regime of sputtering is kept within this scale of parameters. For the voltage above 1500 V discharge becomes unstable and a bend appears on the volt-ampere characteristic, i.e. voltage growth leads to discharge current decrease.

Now we emphasize the following. Working pressure in magnetrons is usually within a range of a few units on 10^{-3} Torr [1]. The accelerator cleans effectively a surface when a pressure is significantly less (4-5.10^{-4} Torr). It may cause a barrier for making a continuously operating line: accelerator – magnetron, when a treated surface is shifted mechanically passing near every device. To solve the problem we take into account the following. Usually the working gas is filled into a volume through the anode or cathode and a pressure in a discharge gap exceeds the one in vacuum chamber significantly. If we make a gas inlet directly into a vacuum chamber omitting the anode, then one can expect an increase of operation pressure in the etching regime. Experiments verify this hypothesis. The rates of a surface cleaning (curves 2 and 2') for the case the working gas is fed into vacuum chamber are shown in Fig. 2. It is seen that the qualitative character of dependencies is the same but an optimum pressure is increased by a factor ~ 2. Maximum cleaning rate is increased by the factor ~ 2 also and achieves a value ~ 1 nm/sec. It is close to a best data obtained for Kaufman source [2]. Rejection of a classic system of a gas inlet simplifies a construction of set-up and its exploitation.



a)

b)

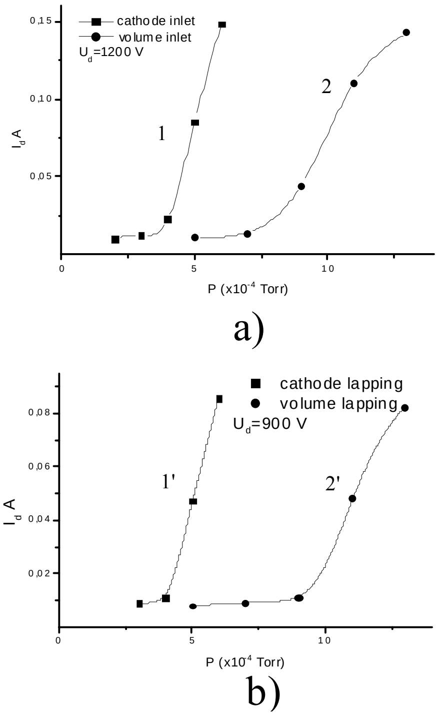
Fig. 2. The dependencies of cleaning rate on pressure in a vacuum chamber under constant voltage on an anode

The volt-ampere characteristics of accelerator for a gas inlet through a source and directly to the chamber are shown in Fig. 3. It is seen, they are the ascending curves typical for the accelerator with the anode layer. A metal collector separated from plasma by a grid under floating potential was installed instead of glass target in order to determine the ion beam current onto substrate. A negative potential 200-400 V providing the ion current saturation is applied to collector. Dependencies of ion beam current on pressure correspond qualitatively to the volt-ampere characteristics of accelerator. Ion beam current is about ten percents of a discharge current.

We note that discharge current and ion beam current are monotonous functions of pressure in system. Nevertheless the dependency of a cleaning rate on the same parameter has an evident maximum. The decreasing of etching rate in the range of high pressure can be attributed to a few causes.

Firstly a decrease of ion beam energy can be expected in this range. To examine this suggestion the following measurements were performed. A metal collector was installed instead of glass target and its floating potential was measured. Dependency of floating potential on gas pressure is shown in Fig. 4. It is readily to see that target potential leaps in a region of cleaning rate decrease. It leads to an ion beam deceleration. Measurements carried out by a multi-grid analyzer prove that energy of ions coming from the anode layer is typical for such kind of source [3]. In this case a jump of floating potential from 300 to 600 V (see Fig. 5) will decelerate the ions significantly, but part of them keeps energy enough for target atoms sputtering.

Second, sputtering of accelerator cannel walls grows rapidly in a range of high pressure and high discharge current [3]. Significant part of atoms knocked out from cathode deposit on substrate. Cleaning rate of target is defined by competition of this process with target ion sputtering. For pressure above 6×10^{-4} Torr (for the common gas inlet) and 10^{-3} Torr (for inlet directly into a volume) cathode sputtering becomes a dominant factor and cleaning regime is substituted by regime of sputtering.



a)

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Fig. 3. The volt-ampere characteristics of accelerator for a gas inlet through a source and directly to the chamber

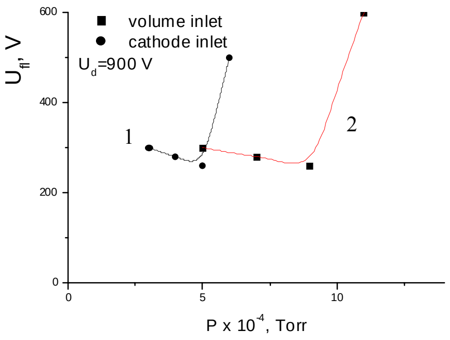

Fig. 4. The dependencies of target floating potential on residual gas pressure

For definition of a influence degree of the different factors on transition of a system in a sputtering mode we added in the chamber the heated cathode. If there is the emitter of electrons for the target surface charge compensation, it floating potential is lowered up to zero and the mode of cleaning is saved up to pressure $2{,}2x10^{-3}$ Torr. The floating potential increases because of unsufficient issuing ability of the termo-issuing cathode is observed further.

All said is shown that the recession on curve of the target cleaning rate is determined mainly by sharp growth of a target potential at transition of operating pressure in area of 10-3 Torr.

Considering a problem of ALA compatibility with the magnetron, it is necessary to take into account one more factor. In the sputtering process of complex coatings as a plasma creation environment the multicomponent gas mixtures quite often use. Most frequently use the small quantities (~ 10 %) nitrogen or oxygen. Therefore we have checked up as such components rate of cleaning of the target influence. The experiments have shown, that the nitrogen to argon has not an noticeable effect for activity of the accelerator at it partial pressure up to 30 %. The same quantities of oxygen can result in an essential drop of clearing rate, down up to 3 times. The most probablis reason of the mentioned drop of rate can be formation of copper oxides on a cleared surface.

CONCLUSION

Thus, in this work we found:

1. Accelerator with an anode layer without forced compensation of ion beam space charge cleans a surface of solid state intensively in a narrow range of gas pressure. AAL doesn't yield the Kaufman ion source by absolute cleaning rate (~ 1 nm/sec).

2. Gas inlet into the accelerator through the anode can be changed by inlet directly a vacuum chamber. In this case sputtering rates are increased by the factor about 2. Pressure optimal for cleaning increases essentially providing compatibility of AAL with a magnetron by working gas pressure.

3. Major factor determining a drop of the target cleaning rate in the field of high pressure, is the growth of a floating potential of a dielectric substrate. In case of forced compensation of a potential of a plasma flow the influence of sputtering of electrodes and defocusing of a beam can be neglected.

4. The mixing in plasma creation gas of nitrogen (up to 30 %) has not an noticeable effect for activity of the accelerator. However, the mixing of the same quantities of oxygen can result in an essential drop of clearing rate (down up to 3 times).

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